DTU Library

Uptake and fate of organic contaminants in plants of constructed wetlands

Rein, Arno; Legind, Charlotte Nielsen; Nielsen, Mette Algreen; Trapp, Stefan

Publication date:
2012

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Rein, A., Legind, C. N., Nielsen, M. A., & Trapp, S. (2012). *Uptake and fate of organic contaminants in plants of constructed wetlands*. Poster session presented at 4th International Congress of the European Soil Science Societies Eurosoil 2012, Bari, Italy.

DTU Environment
Department of Environmental Engineering

Technical University of Denmark

timbre

Uptake and fate of organic contaminants in plants of constructed wetlands

Arno Rein *, Charlotte N. Legind, Mette Algreen, Stefan Trapp

** arnr@env.dtu.dk*

Introduction

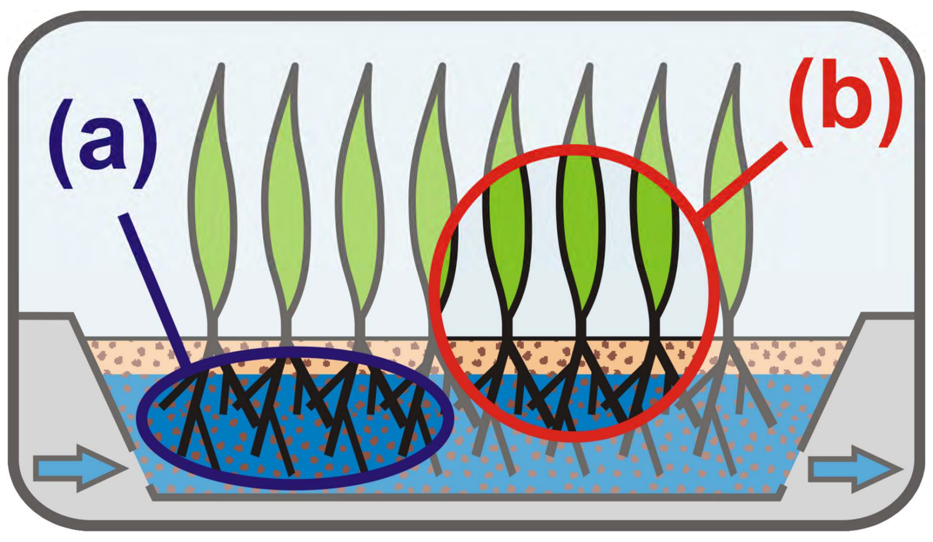
- Constructed or natural wetlands may act as buffer stripes for polluted groundwater with high metabolic activity between groundwater and rivers
- Experimental wetlands established in Leuna and Bitterfeld, Germany [1]
- In the presence of plants, a significant stimulation of substance removal (e.g. benzene, MTBE) was observed

Objective & Aim

- **Objective:** developing a model approach for evaluating the effect of plants on chemical removal from water & modelling of experimental wetlands
- **Aim:** identification of relevant processes and prediction of contaminant fate and removal potential

Wetland & simulation studies

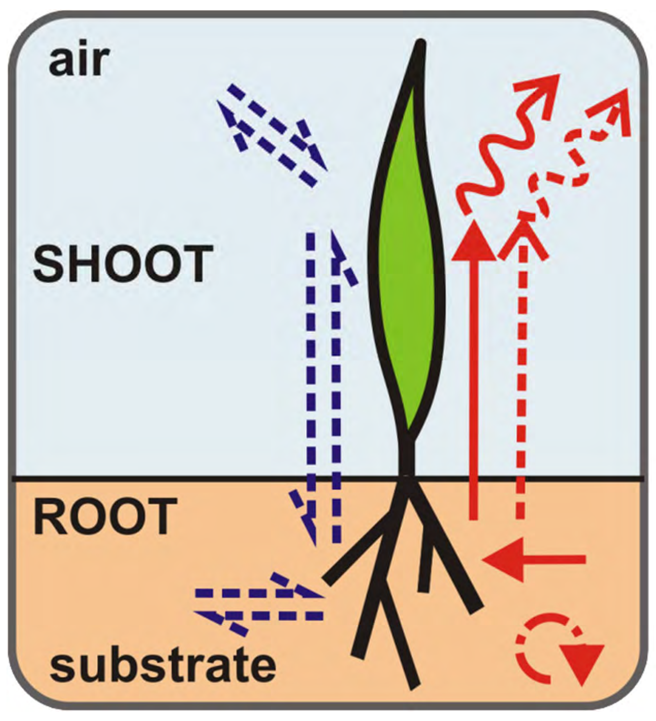
- Horizontal flow subsurface wetland, planted with reed (*Phragmites australis*) & unplanted controls [1]



(a) reactive transport modelling with MIN3P, unsaturated and saturated flow [2]; root uptake included as loss term

(b) PLANT MODELLING

Model concept & processes



- **Uptake** into plants with water & subsequent phytovolatilisation
- **Chemical efflux** through plant **aerenchyma** with air (CO_2)
- Aerobic, anaerobic & rhizome mediated **degradation**
- **Oxygen balance**, O_2 influx & CO_2 efflux via aerenchyma
- Gaseous deposition & volatilisation to/from substrate

Model details

- Inhomogeneous linear ordinary differential equations (**ODEs**) for the change of concentration in **substrate**, **root** and **shoot**
- **Multi-cascade approach** [3,4]: **analytical solution** of the ODEs, **principle of superposition** to obtain the dynamic solution: simulation subdivided into 24 periods with constant conditions (concentration vector **C**(t) at the end of specific period serves as initial conc. vector **C**(0) for next period in all compartments); the model follows flow of water through wetland, each of the 24 periods cover 1/24th of hydraulic retention time

Change of concentration in substrate:

$$\frac{dC_S}{dt} = \left(\frac{A_S\, P_S\, \rho_{S,wet}\,(1-f_P)}{K_{AW}\, K_{WS}\, M_S} + \frac{A_S\, v_{dep}\, f_P}{M_S} \right) C_A - \left(\frac{Q\, K_{WS}}{M_S} + \frac{A_S\, P_S\, \rho_{S,wet}\, 1000L\, m^{-3}}{M_S} + \underbrace{k_{anaerobic} + k_{aerobic} + k_{rhizome} + k_{effluxwithCO_2}}_{\text{rate constants for degradation and efflux with } CO_2} \right) C_S$$

input from air (gaseous & particulate deposition

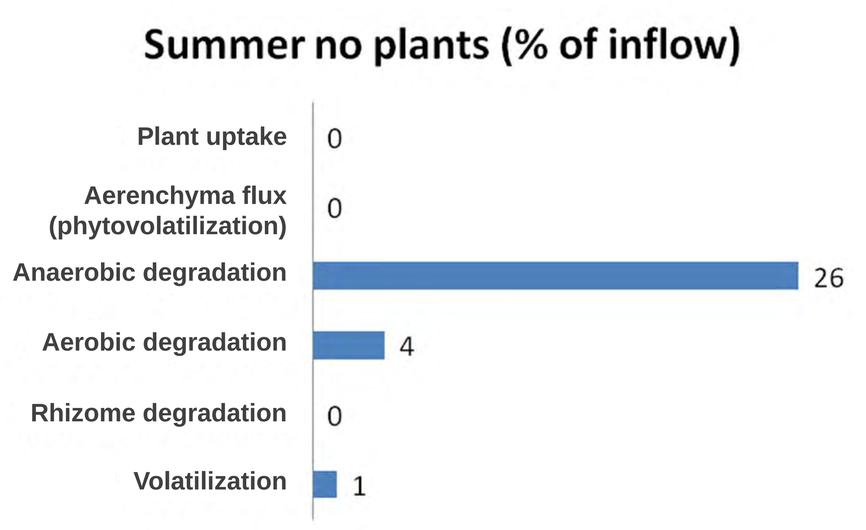
volatilisation loss

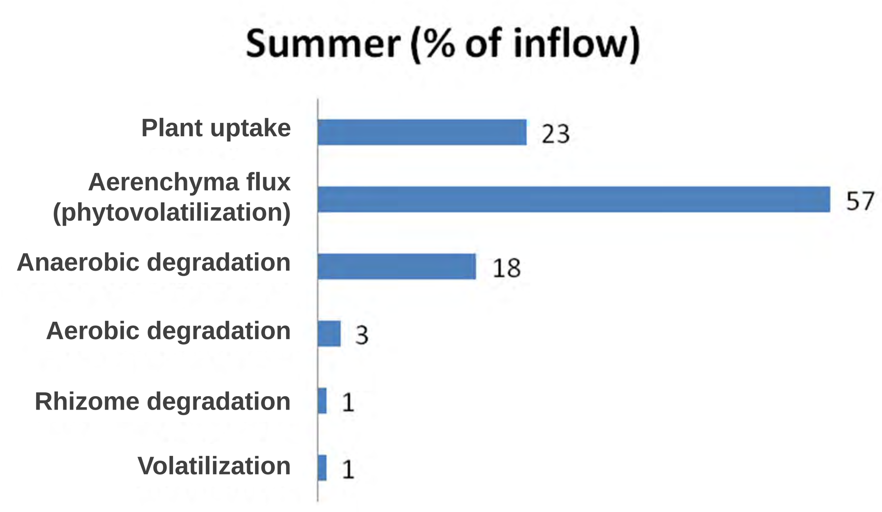
root uptake from substrate water with transpiration stream

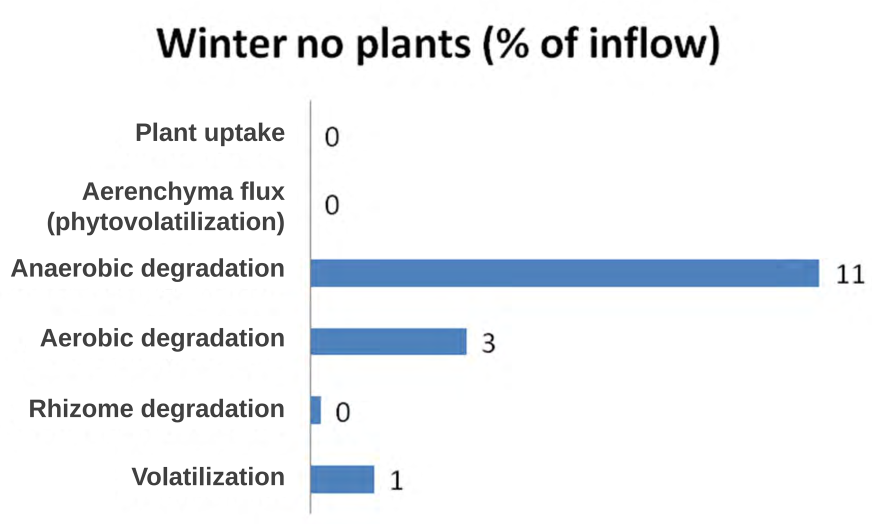
rate constants for degradation and efflux with CO_2

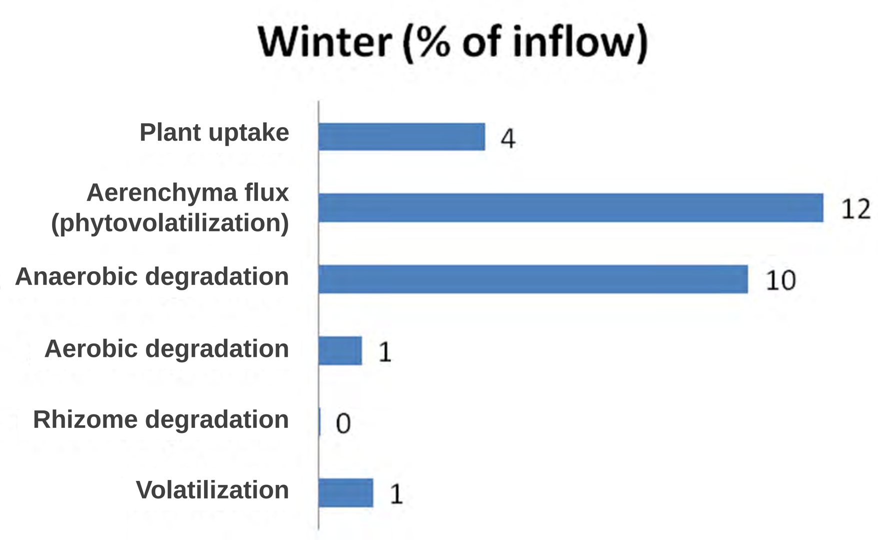
Example results - BENZENE in the Leuna wetlands

SIMULATED









MEASURED

Measured fluxes [5,6]	Control wetland	Planted wetland	Period
Total removal	22 %	89 %	Summer
		92 %	June
	23 %	27 %	Feb/March
		59 %	February
Volatili-sation	0 %	2.3 %	Summer
	0.24 %	1.8 %	June
	0 %	0.1 %	Februray
	0 %	0.8 %	Februray

- In summer: 4 times faster removal on planted wetland
- In winter: removal on planted wetland still somewhat higher
- negligible volatilization

Conclusions & outlook

- Important indirect effects identified: plants enable exchange between wetland substrate and air (O_2, aerenchyma)
- Significant plant uptake in summer; probably plants degrade groundwater contaminants (benzene, TCE, chlorobenzene, MTBE)
- Further studies on plant uptake and degradation are on-going (including the support of plants for degrader microbes)
- Models for estimating the phytoremediation potential (including soil and groundwater contamination) will be (further) developed
- Future work will also include coupling of the plant uptake model to MIN3P for dynamic simulations of the whole system

SEVENTH FRAMEWORK PROGRAMME

Acknowledgements

This work was funded by the Helmholtz Centre for Environmental Research - UFZ, Germany (research program SAFIRA II)

and by the European Commission (Seventh Framework Programme FP7, Contract No. 265364, project timbre)

References

[1] Braeckevelt M. et al. *Ecological Engineering* 2011, 37(6): 903-913. [2] Maier U, DeBiase C, Baeder-Bederski O, Bayer P. *Journal of Hydrology* 2009, 369: 260-273. [3] Rein A, Legind CN, Trapp T. *SAR QSAR Env Res* 2011, 22: 191-215. [4] Legind CN, Kennedy CM, Rein A, Snyder N, Trapp S. *Pest Management Science* 2011, 67: 521-527. [5] Reiche N, Lorenz W, Borsdorf H. *Chemosphere* 2010, 79(2): 162-168. [6] Seeger EM et al. *Environ Sci Technol* 2011, 45, 8467–8474.

Contact

Dr. Arno Rein, Dept. Environmental Engineering, Technical University of Denmark, Miljøvej Bd. 113, DK-2800 Kgs. Lyngby, Denmark; arnr@env.dtu.dk

timbre